LLNL Environmental Restoration Division (ERD)
Standard Operating Procedure (SOP)

ERD SOP 1.1: Field Borehole Logging—Revision: 4

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CONCURRENCE:	**Date**
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1.0 PURPOSE

The purpose of this SOP is to describe the physical characteristics of sediments and rock encountered during auger, rotary, punch core or core drilling and to document the procedures used during geophysical logging and the collection of subsurface samples for chemical analysis.

2.0 APPLICABILITY

The following procedures should be reviewed and followed by all personnel performing any borehole logging activities.

3.0 REFERENCES

3.1 American Society for Testing and Materials (1991), *Standard Method for Penetration Test and Split-Barrel Sampling of Soils*, ASTM D:1586-84, Vol. 04.08, 232-237.

3.2 American Society for Testing and Materials (1991), *Standard Practice for Diamond Core Drilling for Site Investigation*, ASTM D:2113-83, Vol. 04.08, 260-263.

3.3 American Society for Testing and Materials (2000), *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*, ASTM D:2488-90, Vol. 04.08, 320-329.

3.4 Environmental Protection Agency (1987), *A Compendium of Superfund Field Operations Methods*, EPA/540/P-87/001.

3.5 Johnson, R. B., and J. V. DeGraff (1988), *Principles of Engineering Geology*, John Wiley and Sons, New York.

3.6 Terzaghi, K., and R. B. Peck (1967), *Soil Mechanics in Engineering Practice*, 2nd ed., John Wiley and Sons, New York.

3.7 U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control (1997), *NIOSH Pocket Guide to Chemical Hazards*, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

4.0 DEFINITIONS

See SOP Glossary.

5.0 RESPONSIBILITIES

5.1 Division Leader

The Division Leader's responsibility is to ensure that all activities performed by ERD at the Livermore Site and Site 300 are performed safely and comply with all pertinent regulations and procedures, and provide the necessary equipment and resources to accomplish the tasks described in this procedure.

5.2 Hydrogeology Group Leader (HGL)

The HGL's responsibility is to ensure that proper procedures are followed for activities (i.e., drilling, borehole logging and sampling, monitor well installations and development).

5.3 Drilling Supervisor (DS)

The DS plans all drilling related activities and coordinates the drilling contractor schedules and equipment needs.

5.4 Drilling Coordinator (DC)

The DC provides the interface between the DS, Subproject Leader (SL), Hydrogeologist (HG) and the field activities and is responsible for coordinating the borehole logging activities with the Drilling Geologist (DG).

5.5 Drilling Geologist (DG)

The DG is responsible for conducting borehole logging safely and correctly per established operational and safety procedures, and to inform the DC and SL of any nonconformances.

5.6 Subproject Leader (SL)

The SL is responsible for the overall investigation, planning, assessment, and remediation within a study area, including decisions regarding borehole depths and well specifications.

5.7 Hydrogeologist (HG)

The HG is responsible for arranging the review of borehole and geophysical logs, and assisting the SL in conducting his/her responsibilities, as listed above.

6.0 PROCEDURES

6.1 Preparation

6.1.1 Prior to field borehole logging, perform the applicable preparation activities described in SOP 4.1, "Instructions for Field personnel."

6.1.2 Obtain materials listed in the Drilling Geologist Equipment Checklist (Attachment A) and obtain the appropriate personal protection equipment (PPE) (SOP 4.1).

6.1.3 Review the drilling workplan and meet with the SL and HG to determine scope of work and logging intervals.

6.2 Safety Considerations

6.2.1 DGs who are new to the LLNL project will receive direct field supervision during borehole logging from an experienced geologist for at least the first three logging days.

6.2.2 Regularly monitor drill cuttings and work area with a photoionization detector (PID) or flame ionization detector (FID). Cease drilling operations and contact the Site Safety Officer (SSO), HGL, DC, DS, and/or the appropriate Hazards Control Team as appropriate when:

- Readings exceed the time-weighted average (TWA) values, or exceed half of the threshold limit values (TLV) for known or suspected chemicals (see Attachment B for selected contaminant exposure limits),
- Breathing zone concentrations recorded by the field monitoring exceed twice background concentrations,
- 5 ppm is measured in the absence of background concentrations, or
- There is evidence of contamination that could impact worker health and safety.
- Depending on location, an alpha-beta meter may be required.

6.3 Logging Procedure

Field borehole logging is one aspect of drilling operations. Other aspects are covered in SOPs 1.2, "Borehole Sampling of Unconsolidated Sediments and Rock;" 1.3, "Drilling;" 1.4, "Monitor Well Installation;" and 1.5, "Monitor Well Development." Every borehole should be logged whether or not a monitoring well will be installed. If coring is not

conducted while drilling, cuttings should be logged while allowing for lag time due to depth. Contacts should be estimated based upon lithology changes and drill rig behavior. If continuous coring is conducted, the core should be logged while in the polyvinyl chloride (PVC) tray.

6.4.3.6 Auger Drilling

1. Observe cuttings and note drill rig behavior.
2. Collect split-barrel sample or continuous core as directed in the field.

6.4.3.6 Wireline Coring

6.4.3.6 Attempt continuous coring if possible.

2. Observe drill cutting composition, mud/water or cutting color changes, fluid pressure, and rig behavior when there is potential partial core recovery.

C. Rotary Drilling

1. Observe cuttings, note drill rig behavior, fluid pressure, and mud or water color changes. Obtain input from driller if uncertain about lithology intervals.
2. Collect split-barrel or punch core as directed in the field protocol.

6.4 Borehole/Well Construction Log Completion Procedure

Complete the Borehole/Well Construction Log as described below. Attachment C is an example of a blank boring log. The last digit in each Subsection below corresponds to the numbers listed in parentheses in Attachment C of this SOP. For example, the first description, 6.4.1 Borehole Location, should be entered in the space marked **(1)** BOREHOLE LOCATION on the blank boring log (Attachment C).

6.4.1 **Borehole Location**. Indicate on a map, preferably an Autocad produced drawing, the borehole location with respect to permanent natural and man-made features and any existing nearby wells. When feasible, record distance to at least two permanent locations or one location when directional (i.e., compass bearing) data are provided. Show a north arrow preferably oriented toward the top of the page.

6.4.2 **Project**. Identify the project as Lawrence Livermore National Laboratory (LLNL) Site 300 or Livermore Site. In addition, include the general area in which the borehole is located (e.g., off site, Building 834, T-5475).

6.4.3 **Borehole/Well Number**. The borehole/well number as provided by the field protocol.

6.4.4 **Job Number**. Identifies the release order (KSD) number for the project.

6.4.5 **Logged By**. Identifies the individual(s) responsible for logging the borehole, performing field measurements, and collecting samples.

6.4.6 **Edited By**. Identifies the geologist who independently reviews and checks the boring/well log entries.

6.4.7 **Project Manager**. Identifies the SL.

6.4.8 **Drill Rig**. Identifies drill rig manufacturer and model.

6.4.9 **Drilling Contractor**. Identifies the drilling company and its city of origin.

6.4.10 **Driller/Helper**. Identifies drill rig operator and helper(s).

6.4.11 **Drilling Method**. Identifies the method(s) used to drill the borehole.

6.4.12 **Sample Method**. Identifies the method(s) used to collect lithologic and chemical samples.

6.4.13 **Hammer Weight/Drop**. The drive sampler hammer weight in pounds and drop distance in inches for the hammer used to advance drive samplers.

6.4.14 **Bentonite Gel Used**. Indicate whether or not bentonite gel was used as a drilling fluid. If so, identify the product name and manufacturer. No polymer-bearing drilling fluid additives shall be used unless approved in advance by the Environmental Chemistry and Biology Group Leader.

6.4.15 **Borehole Diameter**. Diameter of final borehole in inches and tenths of an inch. Also note diameter of any pilot boreholes drilled.

6.4.16 **Borehole Started Time/Date**. Identifies time (24 h) and date when drilling began.

6.4.17 **Borehole Completed Time/Date**. Identifies time (24 h) and date when pilot borehole is drilled to total depth.

6.4.18 **Water Source**. Indicates whether or not water was introduced into the borehole during drilling and/or into the well during development. If so, identifies the source (e.g., fire hydrant location, faucet, and number).

6.4.19 **Well Construction Started Time/Date**. Identifies the time (24 h) and date when well construction begins, including reaming the pilot borehole in preparation for well construction

6.4.20 **Well Construction Completion Time/Date**. Identifies time (24 h) and date when well installation is complete (placement of first grout lift). If well is abandoned, note as such.

6.4.21 **Well Head Completion**. Identifies the proposed type of well head completion (e.g., locking 9-in. diameter galvanized steel pipe [“stove pipe”] or Christy box).

6.4.22 **Depth to Water**. Water levels in boreholes should be recorded when water is first encountered during drilling and then at least once after drilling has been completed or a piezometer and/or monitor well has been installed. Before taking water level measurements, review SOP 3.1, “Water Level Measurement.” Include borehole/casing depth, water depth, time, and date using ground surface as the datum.

6.4.23 **Total Depth**. Record total depth of borehole in feet.

6.4.24 **Casing Depth**. Record total depth of well casing and screen in feet.

6.4.25 **Screened Interval**. Include depth interval of perforated casing section in feet.

6.4.26 **Sandpack**. List depth interval of filter pack sand and fine sand in feet. Include manufacturer name and designation of sand.

6.4.27 **Well Development**. Identifies the method(s), and time (24 h), date, and estimated flow rate in gallons per minute (gpm) when initial well development was completed.

6.4.28 **Geophysical Logs**. Identify geophysical logging company, method(s), and date. If geophysical logging is not performed during initial drilling and well installation, enter NA (not applicable).

6.4.29 **Circulation**. Volume of fluid losses and the interval over which they occur. When the column is left blank, it indicates that no fluid loss was observed. Complete fluid loss (CL) means that no fluid returned to the surface during pumping. If possible, give quantitative estimates of major fluid losses (rate: in gpm, or estimate of total gallons lost). Although the above mentioned circulation loss applies primarily to air and mud rotary systems, it can also be used during auger drilling to indicate quantity of return of cuttings at the surface.

6.4.30 **OVA/PID Field Readings**. Record Organic Vapor Analyzer (OVA) or PID readings. The work area (breathing zone) should be monitored with the OVA/PID for each core run. A portion of each soil/rock sample submitted for analysis should also be monitored with the OVA/PID after being containerized in a plastic bag for 15 minutes.

6.4.31 **Sampler Type/Depth**. Give sampler type by the letter code listed below and identify the depth at the top of the sampling interval in feet below ground surface (bgs).

Sampler type	Inside diameter (in.)	Code
Standard penetrometer	1.38	SP
Split-barrel (small)	2.0	SBS
Split-barrel (large)	2.5	SBL
HQ wireline core	2.3	PC

6.4.32 **Blows/6 inches**. The number of blows required to drive the sampler 6 in. by a 140-lb hammer falling 30 in. Fifty blow counts per 6-in drive is considered "refusal," and sampling at this depth is usually terminated. In addition, a total of 100 blow counts per 18-in. drive, or no observed advance of the sampler during ten successive hammer blows, is also considered "refusal." During coring, leave this section blank. Normally, the second and third 6-in. intervals are recorded and added as the number of blows per feet.

6.4.33 **Inches Recovered/Inches Driven**. The length in inches of sediment or rock recovered on a sampling or core run divided by the length in inches the sampler is advanced. For example, a recovery ratio for 10 in. of recovery on a 18-in. sampling interval for a core run would be:

$$\frac{10}{18}.$$

6.4.34 **Sample Condition/Rock Quality Designation (RQD)**. Indicates the estimated quality of the sample for analysis: P = poor, F = fair, G = good, E = excellent. When rock coring, the RQD is reported in the unreduced fraction form. The numerator is the length in inches of intact core 4 inches or greater in length, and the denominator is the length of the core run in inches.

6.4.35 **Sample Identification (ID)**. Depth at the top of the sampling interval is given in feet and tenths of feet. The date and time of the sample is also given.

Livermore Site:

For soil samples collected at the Livermore Site, the sample designation distinguishes between unsaturated samples (B-#-depthU) and saturated samples (B-#-depthS). For example, a soil sample collected from borehole B-1604 at a depth of five feet in the unsaturated zone would be identified as B-1604-5.0U.

Site 300:

For soil samples collected at Site 300, no designation is made between unsaturated and saturated; instead, the sample name ends in "F" (for feet). For boreholes drilled for monitoring well installation, the sample name begins with "W". For boreholes drilled without well installation, the sample name begins with the borehole number (without a letter, such as W or B). For example; a soil sample collected from borehole W-865-05 (planned for well installation) at a depth of five feet would be identified as W-865-05-5.0F. A soil sample collected from borehole 834-C1 (not planned for well installation) at a depth of five feet would be identified as 834-C1-5.0F.

Duplicate soil samples are to be named as in the following example: W-865-05-(150.3)-DUP-150.0F where 150.3 is the real depth and 150.0 is the depth of the routine sample for which it is the QA.

Groundwater grab samples collected from the open borehole (before well installation) are to be named as in the following example: W-865-05-BGW-52.0F where 52.0 is the borehole depth at the time of sample collection.

6.4.36 **Analysis**. Identifies laboratory analysis to be performed on sample.

6.4.37 **Well Annulus/Borehole Filler**. Identifies the type of material used to fill the annulus space between the well and borehole wall (i.e., Monterey #3 sand, 0/30 sand, bentonite pellets, portland cement grout). Identifies the type of material used as borehole filler, either for backfill below the well bottom or for abandoning the borehole, if required (i.e., portland cement grout, bentonite chips, etc.). Material names are written vertically and arrows are drawn from the material name to the upper and lower contacts with adjacent materials.

6.4.38 **Well Casing**. Identifies the casing and screen used to construct the well. Casing and screen identification should include type of material (PVC, steel, etc.), schedule (Sch 40, Sch 80, etc.), and diameter. Screen identification should also include slot size (i.e., 0.02-inch). The well cap location should be noted. Casing and screen descriptions are written vertically and arrows are drawn from the description to the upper and lower contacts with adjacent descriptions.

6.4.39 **Depth in Feet**. Identifies the depth in feet. The depth on all pages other than the first page should be filled out by the drilling geologist in the field.

6.4.40 **Recovery/Sample Location**. Sample recovery is shown graphically by an "x" in the recovery column on the log. The location of a sample collected for further evaluation is shown by a solid box. When partial sample loss occurs, it is often possible to determine why and where core loss has occurred. For example:

1 Rock stuck in drive shoe.

2 Coring from dense (stiff) material to soft material causing block-off.

3 Loss of cohesionless material.

4 Fell out during retrieval of core sampler.

5 Mechanical failures.

Note: If uncertain where sample loss has occurred, recovered interval is assumed to be from the top of the sampling interval.

6.4.41 **Contact**. Lithologic contacts are drawn in the contact column and extended across the lithologic description field. If the contact is identified by the driller, specify this in the lithologic description field. Three types of contacts are used:

1. Sharp. A sharp contact is indicated with a solid line.
2. Gradational. A gradational contact is indicated with hatches.
3. Approximate. An approximate contact is indicated by a dashed line and is used when the exact depth or nature of the lithologic contact is uncertain.

6.4.42 **Lithologic Description**. A continuous log of encountered geologic materials determined from borehole cuttings, samples, and core should be recorded on the Borehole/Well Construction Log. A system of description similar to the American Society for Testing and Materials (ASTM) method D 2488-90 (2000), *Standard Practice for Description and Identification of Soils* (Visual-Manual Procedure), is used for sediment, and a similar description is used for rock. Lithologic descriptions record direct field observations. Any interpretations included with these descriptions should be clearly noted by placing the interpretation in parentheses. Appendix C2 includes a completed Borehole/Well Construction Log. The format is outlined below:

A. Fine-Grained Sediment Description Format.

1. Contact depth in feet and tenths of a foot. For example, "(0'–5.1')."
2. Textural Classification. The appropriate classification as listed in Attachment D. For example, "Sandy Silt."
3. Group Symbol. The appropriate Unified Soil Classification System (USCS) sediment group symbol as listed in Attachment E is written in parentheses after the textural classification. For example, "(ML)."
4. Color. Soil color is named and coded using the Munsell Soil Color chart. The code should be in parentheses immediately following the written description. Presence of mottling and banding is also recorded. For example, "reddish brn (5YR, 4/4)."
5. Consistency/Penetration Resistance. For fine sediments use very soft, soft, medium, stiff, very stiff, and hard. These are estimated from drive sample hammer blows or other field tests. Blow counts may also be used, if reliable.
6. Moisture Content. Dry, damp, moist, wet (saturated). Attachment F contains a description for each moisture term. Omit moisture terms below the regional water table and when drilling with mud or air-mist rotary systems.
7. Size Distribution. Approximate percentage of gravel, sand, fines (if possible, distinguish between silt and clay). Percentages should add up to 100%. For example, "80% silt, 20% f-sand."

8. Estimated Permeability. Very low, low, moderate, or high. These are based primarily on grain size and sorting. See Section 6.4.43 for abbreviations used for estimated permeability. For example, “LEK.”
9. Miscellaneous. Odor, contact and/or bedding dip, bedding features, cementation, structures, fractures, fracture fillings, fossils, formation name, minerals, oxidation, etc.

B. Coarse-Grained Sediment Description Format.

1. Contact depth in feet and tenths of a foot. For example, “(0'–5.1').”
2. Textural Classification. The appropriate textural classification as listed in Attachment D. For example, “Silty Gravel.”
3. Group Symbol. The appropriate Unified Soil Classification System (USCS) sediment group symbol as listed in Table Attachment E is written in parentheses after the textural classification. For example, “(GM).”
4. Color. Soil color is named and coded using the Munsell Soil Color chart. The code should be in parentheses immediately following the written description. Presence of mottling and banding is also recorded. For example, “dk brn (7.5 YR, 3/4).”
5. Relative Density/Penetration Resistance. For cohesionless materials use very loose, loose, medium, dense, or very dense estimated from drive sample hammer blows or other field tests. Blow counts may be used, if reliable.
6. Moisture Content. Dry, damp, moist, and wet (saturated). Attachment F contains a description for each moisture term. Omit moisture terms below the regional water table and when drilling with mud or air-mist rotary systems.
7. Size Distribution. Approximate percentage of gravel, sand, and fines (silt and clay). Percentages should add up to 100%. For example, “80% gravel, 20% silt.”
8. Grain Shape. Angular, subangular, subrounded, rounded, or well-rounded, for grains larger than sand size.
9. Grain Size. The largest cross-sectional dimension measured in tenths of an inch for grains larger than sand size.
10. Estimated Permeability. Very low, low, moderate, or high. This is based primarily on grain size and sorting. See Section 6.4.43 for abbreviations used for estimated permeability. For example, “HEK.”
11. Miscellaneous. Odor, contact and/or bedding dip, bedding features, sorting, structures, fossils, cementation, geologic origin, formation name, minerals, oxidation, etc.

C. Fine-Grained Rock Description Format

1. Contact depth in feet and tenths of a foot. For example, “(76.5'–80').”
2. Textural Classification. The appropriate classification as listed in Attachment D. For example, “Sandy Siltstone.”

3. Color. Rock color is named and coded using the Geological Society of America rock color chart. The code should be in parentheses immediately following the written description. Presence of mottling and banding is also recorded. For example, "gry grn (5G, 5/2)."
4. Hardness. Very hard, hard, medium, soft, very soft. Attachment G contains a description for each hardness term.
5. Moisture Content. Dry, damp, moist, wet (saturated). Attachment F contains a description for each moisture term. Omit moisture terms below the regional water table and when drilling with mud or air-mist rotary systems.
6. Size Distribution. Approximate percentage of gravel, sand, and fines (silt and clay). Percentages should add up to 100%. For example, "80% silt, 20% f-sand."
7. Estimated Permeability. Very low, low, moderate, or high. This is based primarily on grain size, sorting, and cementation. Estimate secondary permeability due to natural rock fractures when applicable. For example, "LEK."
8. Miscellaneous. Odor, contact and/or bedding dip, cementation, bedding, inclusions, secondary mineralization, fossils, structures, formation name, and fractures.
9. Fractures are identified by depth, angle, width, and associated mineralization if applicable. The interpretation of the fracture type (i.e., as natural [N], coring induced [CI], or handling induced [HI]) should be stated. For example, "NF @90.8', 25 deg to axis, 0.1" wide, minor calcite."

D. Coarse-Grained Rock Description Format

1. Contact depth in feet and tenths of a foot. For example, "(122'–125.7')."
2. Textural Classification. The appropriate classification as listed in Attachment D. For example, "Sandstone."
3. Color. Rock color is named and coded using the Geological Society of America rock color chart. The code should be in parentheses immediately following the written description. Presence of mottling and banding is also recorded. For example, "gry olive grn (5GY, 3/2)."
4. Hardness. Very hard, hard, medium, soft, very soft. Attachment G contains a description for each hardness term.
5. Moisture Content. Dry, damp, moist, and wet (saturated). Attachment F contains a description for each moisture term. Omit moisture terms below the regional water table and when drilling with mud or air-mist rotary systems.
6. Size Distribution. Approximate percentage of gravel, sand, and fines (silt and clay). Percentages should add up to 100%. For example, "80% c-sand, 20% silt."

7. Grain Shape. Angular, subangular, subrounded, rounded, or well-rounded, for grains larger than sand size.

8. Grain Size. The largest cross-sectional dimension measured in tenths of an inch for grains larger than sand size.

9. Estimated Permeability. Very low, low, moderate, or high. This is based primarily on grain size, sorting, and cementation. When applicable, estimate secondary permeability due to natural rock fractures. For example, "HEK."

10. Miscellaneous. Odor, contact and/or bedding dip, cementation, bedding, inclusions, secondary mineralization, fossils, structures, formation name, and fractures.

11. Fractures are identified by depth, angle, width, and associated mineralization, if applicable. The interpretation of the fracture type (i.e., as natural [N], coring induced [CI], or handling induced [HI]), should be stated. For example, "NF @126.1', 35 deg to axis, 0.1" wide, minor calcite"

6.4.43 **Abbreviations Used for Lithologic Descriptions:**

PC = punch core
RC = rock core
v = very
f = fine
m = medium
mod = moderate
c = coarse
min = mineralization
w/ = with
SA = subangular
SR = subrounded
R = rounded
A = angular
soft sed = soft sediment deformation
def'm = deformation
DF = drilling fluid (mud)
x-beds = cross beds
@ = at
RQD = rock quality description
ppm = parts per million
rx w/HCI = reaction with hydrochloric acid
FeOx = iron oxide
MnO2 = manganese oxide
P = plasticity

6.4.44 **Abbreviations Used for Conductivity Estimates**

1 K = primary conductivity
2 K = secondary conductivity due to fracturing, mineralization, etc.
H = high
L = low
E = estimated
K = Hydraulic conductivity

6.4.45 **Core Fractures are Described as Follows:**

(Depth/fracture type (see below)/angle w/mineralization or other characteristics)

CIF = coring induced fracture
HIF = handling induced fracture
NF = natural fracture
HF = healed fracture

6.4.46 **General Abbreviations:**

DA = Drill Ahead
NR = No Recovery
dk = dark
lt = light
ylw = yellow/yellowish
brn = brown/brownish
grn = green/greenish
gry = gray/grayish
blk = black
bl = blue
ind = indurated
cmt = cemented
calc = calcite
qtz = quartz
SS = split spoon
S = sub
//////// = Gradational Contact
------- = Approx. Contact
_____ = Definite Contact

6.5 Post Operation

6.5.1 Store recovered sediment and rock core in core boxes using a black indelible pen to mark sample intervals/runs. Label each box with the location ID, site/OU, depth interval, and box number. Handle core per SOP 1.15, "Well Site Core Handling."

6.5.2 Perform post-work activities described in SOP 4.1, Section 6.3.

6.5.3 Deliver original copies of Borehole/Well Construction Log, Well Development Form, Field Logbook, and all other relevant forms and information to the quality control reviewer for review. After the review, edit documents and copy and distribute files.

7.0 QUALITY ASSURANCE RECORDS

7.1 Borehole/Well Construction Log

7.2 Field Logbook

8.0 ATTACHMENTS

Attachment A—Equipment Check List

Attachment B—Exposure Limits for Selected Contaminants (Table B-1)

Attachment C—Borehole/Well Construction Log

Attachment D—Textural Classifications (Table D-1)

Attachment E—USCS Group Symbols (Table E-1)

Attachment F—Moisture Classifications (Table F-1)

Attachment G—Rock Hardness Classifications (Table G-1)

Attachment A

Drilling Geologist Equipment Checklist

Drilling Geologist Equipment Checklist

____ 300-ft weighted tape
____ Any applicable permits (i.e., excavation, utility clearance, burn permits)
____ Applicable documents (i.e., SSP, OSPs, SOPs, work plan, sample plan, etc.)
____ Appropriate clothing (i.e., coveralls, steel-toed safety shoes, gloves)
____ Barricades/traffic cones
____ Buckets and brushes
____ Caution tape
____ Company ID sign for vehicle
____ Cooler with ice
____ Core boxes, marking pens
____ Deionized water
____ Detergents (Alconox, Liquinox)
____ Disposable Teflon or polyethylene bailers
____ Document control logbook
____ Field forms (i.e., borehole/well constructions form, daily field report forms)
____ Field notebook
____ Fire extinguisher
____ First aid kit
____ Glass jar
____ Grain-size sieves
____ Hard hat
____ Hearing protection
____ Imhoff cone
____ Measuring wheel
____ Munsell soil/rock color chart
____ Nitrile or latex sampling gloves
____ pH paper
____ PID or FID, or gamma/beta meter if required
____ Rock hammer
____ Safety glasses
____ Sample containers/labels
____ Signs listing responsible persons, restricted entry, hearing protection/hard hat/safety glasses/safety shoes required
____ Soil sample tubes
____ Steel measuring tape with engineering scale
____ Steel spatula
____ Stopwatch or watch with second hand
____ String
____ Teflon tape (4 in. wide)
____ Water-level meter
____ Zip-Loc plastic bags

Attachment B

Exposure Limits for Selected Contaminants

Table B-1. Exposure limits for selected contaminants.

Chemical name	Exposure limits (TWA[a])	IDLH[b]
Arsenic	0.002 mg/m^3[c] [15 min]	5 mg/m^3
Barium	0.5 mg/m^3	50 mg/m^3
Benzene	0.1 ppm	500 ppm
	1 ppm[d]	
Freon 113	1000 ppm	2,000 ppm
	(7600 mg/m^3)	
	1250 ppm[d]	
	(9500 mg/m^3)	
Tetrachloroethylene	25 ppm	150 ppm
Toluene	100 ppm	500 ppm
	(375 mg/m^3)	
	150 ppm[d]	
	(560 mg/m^3)	
Trichloroethylene	25 ppm	1,000 ppm
Uranium	0.2 mg/m^3	10 mg/m^3
	0.6 mg/m^3[d]	

[a] Time-weighted average (TWA) concentrations for up to a 10-h workday during a 40-h workweek, unless noted otherwise.

[b] Immediately Dangerous to Life or Health concentrations.

[c] Indicates a ceiling value which should not be exceeded at any time.

[d] Short-term exposure limit is a 15-min TWA exposure that should not be exceeded at any time during a workday.

Note: See reference 3.7 for more information.

Attachment C

Borehole/Well Construction Log

Borehole/Well Construction Log

(1) BOREHOLE LOCATION	**(2)** Project:	**(3)** Borehole/Well No.:
		(4) Job No.:
	(5) Logged By:	**(6)** Edited By:
	(7) Project Manager:	**(8)** Drill Rig:
	(9) Drilling Contractor:	
	(10) Driller/Helper:	
	(11) Drilling Method:	**(12)** Sample Method:
	(13) Hammer Weight/Drop:	**(14)** Bentonite Gel Used:
	(15) Borehole Diameter, Pilot:	Final:
	(16) Borehole Started, Time/Date:	**(17)** Borehole Completed, Time/Date: **(18)** Water Source:
Notes:	**(19)** Well Started, Time/Date:	**(20)** Well Completed, Time/Date:
	(22) Water Depth / Boring/Casing Depth / Time / Date	**(21)** Well Head Completion

ABBREVIATIONS: ------- = Approx. Contact; //////// = Gradational Contact; @ = at; _____ = Definite Contact; 1 K = primary conductivity; 2 K = secondary conductivity due to fracturing, mineralization, etc.; A = angular; bl = blue; blk = black; brn = brown/brownish; c = coarse; calc = calcite; CIF = coring induced fracture; cmt = cemented; DA = Drill Ahead; def'm = deformation; DF = drilling fluid (mud); dk = dark; E = estimated; f = fine; FeOx= iron oxide; grn = green/greenish; gry = gray/grayish; H = high; HF = healed fracture; HIF = handling induced fracture; ind = indurated; K = Hydraulic conductivity; L = low; lt = light; m = medium; min = mineralization; MnO2 = manganese oxide; mod = moderate; NF = natural fracture; NR = No Recovery; P = plasticity; PC = punch core; ppm = parts per million; qtz = quartz; R = rounded; RC = rock core; RQD = rock quality description; rx w/HCI = reaction with hydrochloric acid; S = sub; SA = subangular; soft sed = soft sediment deformation; SR = subrounded; SS = split spoon; v = very; w/ = with; x-beds = cross beds; ylw = yellow/yellowish.

(23) Total Depth: **(24)** Casing Depth:
(25) Screened Interval:
(26) Sand Pack, #3 #0/30:
(27) Well Development Method:
Time: Date: Flow Rate:
(28) Geophysical Logs, Type: **(29)** Circulation:
By: Date

(30) OVA/PID Field Readings (ppm)		**(31)**	**(32)**	**(33)**	**(34)**	**(35)**	**(36)**	**(37)**	**(38)**	**(39)**	**(40)**	**(41)**	**(42)** LITHOLOGIC DESCRIPTIONS
Work Area	Soil/Rock	Sampler Type/Depth	Blows 6 inches	Inches Recovered/Inches Driven	(Sample Condition/RQD	Sample ID	Analysis	Well Annulus/Borehole Filler	Well Casing	Depth in Feet	Recovery/Sample Loc.	Contact	
										1			
										2			
										3			
										4			
										5			
										6			
										7			
										8			
										9			
										10			

Note: Numbers **1–42** listed on this log correspond to Subsections **6.4.1–6.4.42** of SOP 1.1.

Attachment C. Borehole/Well Construction Log.

------- = Approx. Contact; //////// = Gradational Contact; @ = at; _____ = Definite Contact; 1 K = primary conductivity; 2 K = secondary conductivity due to fracturing, mineralization, etc.; A = angular; bl = blue; blk = black; brn = brown/brownish; c = coarse; calc = calcite; CIF = coring induced fracture; cmt = cemented; DA = Drill Ahead; def'm = deformation; DF = drilling fluid (mud); dk = dark; E = estimated; f = fine; FeOx= iron oxide; grn = green/greenish; gry = gray/grayish; H = high; HF = healed fracture; HIF = handling induced fracture; ind = indurated; K = Hydraulic conductivity; L = low; lt = light; m = medium; min = mineralization; MnO2 = manganese oxide; mod = moderate; NF = natural fracture; NR = No Recovery; P = plasticity; PC = punch core; ppm = parts per million; qtz = quartz; R = rounded; RC = rock core; RQD = rock quality description; rx w/HCI = reaction with hydrochloric acid; S = sub; SA = subangular; soft sed = soft sediment deformation; SR = subrounded; SS = split spoon; v = very; w/ = with; x-beds = cross beds; ylw = yellow/yellowish.

(30) OVA/PID Field Readings (ppm)		**(31)**	**(32)**	**(33)**	**(34)**	**(35)**	**(36)**	**(37)**	**(38)**	**(39)**	**(40)**	**(41)**	**(2)** Project:	**(3)** Borehole/Well No.:
Work Area	Soil/Rock	Sampler Type/Depth	Blows 6 inches	Inches Recovered/Inches Driven	Sample Condition/RQD	Sample ID	Analysis	Well Annulus/Borehole Filler	Well Casing	Depth in Feet	Recovery/Sample Loc.	Contact	Notes:	
										1				
										2				
										3				
										4				
										5				
										6				
										7				
										8				
										9				
										0				
										1				
										2				
										3				
										4				
										5				
										6				
										7				
										8				
										9				
										0				

Note: The numbers listed in parentheses on this log correspond to the Subsections listed in Section 6.4 of SOP 1.1 [i.e., **(2)** = **6.4.2**, etc.].

Attachment C. Borehole/Well Construction Log (cont.).

Attachment D

Textural Classifications

Attachment D-1. Textural classifications for the Livermore Site and Site 300.

Type	Classification
Sediment:	
Fine grained	Gravelly silt, sandy silt, silt, clayey silt, sandy clay, silty clay, clay, organic silt, and organic clay.
Coarse grained	Sand, clayey sand, silty sand, gravelly sand, gravel, clayey gravel, silty gravel, and sandy gravel.
Rock:	
Fine grained	Sandy siltstone, siltstone, clayey siltstone, sandy claystone, silty claystone, claystone.
Coarse grained	Sandstone, clayey sandstone, silty sandstone, gravelly sandstone, conglomerate, clayey conglomerate, silty conglomerate, and sandy conglomerate.

Attachment E

Unified Soil Classification System (USCS) Group Symbols

Attachment E-1. USCS sediment symbols.

Fine-grained		Coarse-grained	
Group symbol	Group name	Group symbol	Group name
CL	Low to medium plasticity clays	GW	Well-graded gravel
ML	Nonplastic to medium plasticity silt	GP	Poorly graded gravel
OL	Organic clay or silt (lean)	GM	Silty gravel
CH	High plasticity clays	GC	Clayey gravel
MH	High plasticity silt	SW	Well-graded sand
OH	Organic clay or silt (fat)	SP	Poorly graded sand
PT	Peat	SM	Silty sand
		SC	Clayey sand

Attachment F

Moisture Classifications

Attachment F-1. Moisture classification.

Moisture term	Description
Dry	Absence of moisture to the touch.
Damp	Contains enough water to keep the sample from being brittle, dusty or cohesionless; is darker in color than the same material in the dry state.
Moist	Leaves moisture on your hand, but displays no visible free water.
Wet	Displays visible free water.

Attachment G

Rock Hardness Classification

Attachment G-1. Rock hardness and classifications.

Descriptive term	Defining characteristics
Very hard	Cannot be scratched with knife; does not leave a groove on the rock surface when scratched.
Hard	Difficult to scratch with knife; leaves a faint groove with sharp edges.
Medium	Can be scratched with knife; leaves a well-defined groove with sharp edges.
Soft	Easily scratched with knife; leaves a deep groove with broken edges.
Very soft	Can be scratched with a fingernail.